OAK RIDGE NATIONAL LABORATORY

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FOREIGN TRIP REPORT

ORNL/FTR-3752

DATE: October 5, 1990

SUBJECT: Report of Foreign Travel to India by R. P. Krishnan, Development Staff Member, Engineering Technology Division

TO: A. W. Trivelpiece

FROM: R. P. Krishnan

PURPOSE: The travel was undertaken at the invitation of the United States Agency for International Development (USAID), New Delhi Mission, India. The mission requested assistance from the Oak Ridge National Laboratory (ORNL) and the Pittsburgh Energy Technology Center (PETC), U.S. Department of Energy (USDOE), in reviewing the status, identifying the remaining activities, and the level of technical assistance, and training to be provided from the collaborating U.S. institutions to complete the ongoing coal projects at the Bharat Heavy Electricals Ltd. (BHEL), Trichy, India.

The coal projects are sponsored under the coal component of the Alternate Energy Resources Development (AERD) project of USAID. The PETC has the management responsibility for the coal projects, and the Oak Ridge National Laboratory (ORNL) is providing technical support to the BHEL and the Tata Energy Research Institute (TERI), the collaborating Indian institutions for these projects.

SITES VISITED:		
9/3-4/90	U.S. Agency for International Development, New Delhi, India	R. W. Beckman R. K. Berry N. V. Seshadri
	Bharat Heavy Electricals Ltd., New Delhi, India	K. Ramakrishnan Y. P. Abbi
	Power Finance Corporation (PFC), New Delhi, India	B. M. Pant A. M. Pagedar
	National Thermal Power Corporation (NTPC), New Delhi, India	M. L. Malik N. K. Balasubramaniam

9/5-6/90	Central Power Research Institute, (CPRI), Bangalore, India	S. Anantha Krishnan P. R. Krishnamurthy
9/8-11/90	Bharat Heavy Electricals Ltd., Trichy, India	A. Srinivasulu A. V. Narayanan V. Gopalakrishnan
9/14/90	Power Finance Corporation, New Delhi, India	D. Sankara Guruswamy B. M. Pant A. M. Pagedar N. V. Seshadri
	Department of Non-Conventional Energy Sources (DNES), New Delhi, India	J. Gururaja J. R. Meena N. V. Seshadri
	U.S. Agency for International Development, New Delhi, India	R. W. Beckman A. Scisson T. Mahoney N. V. Seshadri R. K. Berry
	Tata Energy Research Institute, New Delhi, India	R. K. Pachauri P. V. Sridharan
9/18/90	U.S. Agency for International Development, New Delhi, India	D. Pfeiffer R. W. Beckman

ABSTRACT: Under the Phase II, Alternative Energy Resources Development (AERD) project of the United States Agency for International Development (USAID) and the Government of India (GOI), five collaborative coal projects have been initiated in the areas of: (1) NO_x/SO_x control from coal-fired power plants, (2) slagging combustor development for high-ash Indian coals, (3) characterization of Indian coals for combustion and gasification, (4) diagnostic studies for prediction of power plant life expectancy, and (5) environmental and natural resource analysis of coal cycle. The Pittsburgh Energy Technology Center (PETC) has the implementation responsibility for these projects. The Indian collaborative institutions identified for these projects are the Bharat Heavy Electricals Ltd. (BHEL), Trichy, (projects 1-4), and the Tata Energy Research Institute (TERI) for project 5. The Oak Ridge National Laboratory (ORNL) is providing cross-cut technical coordination and support for these five projects.

The traveler and the PETC program manager provided the mission the requested technical assistance in the planning and coordination of the

activities to be taken up in the coal projects under the extension of the AERD project. In conjunction with the BHEL project staff, the level of technical assistance, training, schedule and the budget required for each project were worked out and submitted to the mission. An 18-month time extension beyond December 31, 1990, with additional funding from USAID and BHEL has been recommended to complete the coal projects.

At the request of the mission, the traveler and Dr. William C. Peters met with the technical staff of the PFC, the NTPC, and the CPRI to discuss the new joint initiatives that are being formulated by GOI and USAID in the areas of coal-fired power plant remaining life estimation and extension, and the environment impact of coal-fired power plants. Assistance was provided by ORNL and PETC to these agencies in developing preliminary proposals to GOI and USAID for a life extension demonstration project at a coal-fired utility in India with U.S. experts, and establishing a thermal power research center.

The trip was beneficial to all the participants in the USAID coal projects. The agenda for the follow-on activities were identified. Meetings with the PFC, NTPC, and CPRI were helpful in identifying the role of USAID in future coal-related activities in India.

1. REPORT ON SITE ACTIVITIES AT BHEL, TRICHY

A detailed report on the individual projects is provided in the project summary reports in Appendix A.

The major accomplishments to date and the work to be completed are briefly highlighted.

Project 1 - DEVELOPMENT OF POLLUTION CONTROL STRATEGIES FOR ABATEMENT OF NO_X/SO_X EMISSIONS FROM FOSSIL FIRED PLANTS

In this project, the objective is to quantify the current emission levels of NO_x and SO_x from operating coal-fired power plants to the extent needed to propose pollution control strategies. Baseline monitoring of one or two selected Indian utilities for NO_x and SO_x emissions with technical assistance from U.S. companies will be performed. The equipment and accessories for NO_x/SO_x measurements are being procured in the U.S and will be shipped to India in November-December 1990. The actual monitoring and training of BHEL engineers in U.S. utilities and the recommendations concerning pollution control techniques will be completed between February 1991 and September 1991.

Project 2 - DEVELOPMENT OF SLAGGING COMBUSTOR FOR ADVANCED POWER GENERATION APPLICATIONS

BHEL has designed and erected a 3.0 MW(t) coal-fired slagging combustor at Trichy. The combustor has undergone several modifications based on preliminary trial runs with Indian coals. Only a few trials have resulted in slag formation on the combustor walls. The design and operating parameters for slag formation are yet to be established. Through this collaborative project, the design and operating conditions will be confirmed and appropriate modifications to the existing combustor will be recommended. Technical assistance and diagnostic hardware are being provided by USAID for this project.

Most of the activities to date have been confined to the test site at Trichy in commissioning the combustor and preliminary trial runs. Specifications for the diagnostic hardware to be supplied from the U.S. have been completed and procurement is underway. The design review and the modifications to the existing combustor and testing are planned under the extension phase of the project.

Project 3 - ADVANCED DIAGNOSTIC STUDIES FOR PREDICTION OF LIFE EXPECTANCY OF EXISTING POWER PLANTS

Under this AERD project, technical assistance is being provided to BHEL in the areas of diagnostic techniques for prediction of remaining life and life extension of coal-fired power plants.

The major accomplishments to date have been the visits of two EPRI technical experts and an EPRI consultant to BHEL, Indian utilities and power agencies. Through these visits, the current practices and methodologies used for prediction of remaining life of power plant components in the U.S. were communicated to the Indian engineers. Two seminars and two workshops were conducted in India with the participation of the Indian utilities, boiler vendors and power research agencies to disseminate the information. USAID supplied equipment for this project have been finalized. Follow-up visits of BHEL engineers to U.S. utilities for training in these equipment and site visits to U.S. utilities are planned during the extension phase of the project.

Project 4 - BHEL FUEL EVALUATION TEST FACILITY

The impact of coal quality on boiler output and operation is quite significant and cannot be judged by laboratory data on coal composition and ash properties. Pilot-scale combustion tests are mandatory to provide boiler performance data on combustion efficiency, fuel ignition characteristics, flame stabilization, slagging, fouling, erosion and corrosion of boiler components, and gaseous and particulate emissions. Pilot-scale tests are also necessary for the selection of the appropriate coal and/or coal mixtures for full-scale burning in commercial boilers. In India there is no facility available to conduct screening tests on coal. The USAID/BHEL facility will be the first, state-of-the-art, pilot-scale, fuel evaluation test facility (FETF) in the country. A 3.0 million Btu/h FETF will be erected at Trichy. The primary features of the facility include:

- Simulation of a commercial utility boiler with bottom ash pit, firebox, radiant section, nose section, convection pass and exhaust section.
- Variable firing modes; tangential front and opposed wall.
- Multifuel (coal and oil) and cofiring capabilities.
- Simultaneous feed of different fuels.
- Removable sections in the radiant zone to vary combustor volume and residence time.
- Variable volumetric heat release operation.
- Operation at a wide range of fuel-to-air ratios.
- Adjustable air preheat temperatures (70° to 750°F).
- Flue gas recirculation through the burners and furnace hopper for NO_x control.
- Fouling probes in the convection zone.
- Erosion monitoring in the convection tube surfaces.
- Corrosion monitoring of the radiant and convection tube surfaces.
- Continuous flue gas monitoring (O_2, CO_2, CO, SO_2, NO_x).
- Particulate collection and analysis at selected locations in the combustor, including baghouse.
- Monitoring of critical parameters to perform complete mass and energy balances.

In addition, the facility will be equipped with:

- A computer-based data acquisition and control system.
- Photographic and video recording of flame patterns and ash deposition.
- Advanced diagnostic instrumentation and analytical support.

The engineering design, layout and structural support drawings have been completed. Pending a final review at PETC in October 1990 when two BHEL engineers are expected to visit PETC for the testing of Indian coals in the PETC combustor, the FETF design is essentially complete. All USAID supplied equipment for this project have been identified and procurement has been initiated by PETC. Two coal samples for the baseline tests at PETC have been shipped from India, and eight weeks of testing is planned in October-November 1990. Manufacturing of the components for the FETF, site preparation and erection are planned after December 1990. The activities beyond December 1990 are described in Appendix A.

2. SITE VISIT TO CPRI, BANGALORE

On September 5-6, 1990, the traveler and Dr. Peters visited CPRI. The Central Power Research Institute is an autonomous organization under the Ministry of Energy, Government of India, functioning as the national power research organization covering the fields of generation, transmission, distribution and operation of electricity supply systems. The objectives of the institute include coordination of R&D activities in the power sector and serving as a national testing and certifying authority for transmission systems.

In the area of thermal power generation, the institute is active in its interaction with the various state-owned electric utilities in the country. Major R&D programs are in the areas of coal characterization and testing (erosion and wear), water chemistry, failure analysis of power plant components/systems, and field performance evaluation of pollution control systems (ESPs and bagfilters).

The efforts over the last five years have culminated in the establishment of a Thermal Power Research Center under CPRI direction at Koradi, Nagpur. The project was approved by the Government of India in August 1990 and will be implemented in the next four years. The budget is roughly U.S. $11.0 million.

In the discussions with CPRI, the following topics were identified for collaborative studies:

(1) Optimization of coal combustion system design for efficiency enhancement and pollution minimization
(2) Technoeconomic evaluation of coal beneficiation through pilot-scale testing and a commercial demonstration.
(3) Techniques and methodologies for life expectancy prediction for power plant components.
(4) Environmental impact assessment of coal-fired power plants and criteria for power plant siting.

(5) Flyash utilization

Assistance from the USAID will be in the form of:

i) U.S. technical expertise on state-of-the-art methodologies, selection of instrumentation for the thermal research facility, design review, and assistance during the erection and commissioning of the test facility.
ii) Training of CPRI staff with collaborating U.S. research institutions.
iii) Technical reports, literature and computer software.
iv) Short- and long-term assignments in the U.S. for CPRI personnel for training and technology transfer.
v) Organization and attendance in workshops and seminars in the U.S. and participation of U.S. experts in such meetings in India.

A proposal has been submitted by CPRI to the Ministry of Power enlisting the support required from USAID for this project. A decision will be made in early 1991. ORNL and PETC will be involved in the peer review of the CPRI proposal with other GOI agencies and in making the final recommendations to USAID.

3. MEETINGS WITH POWER FINANCE CORPORATION (PFC)

PFC is responsible for the overall planning, developing investment strategy, and funding of power plant renovation and modernization (R&M) projects in India. PFC plans to spend about U.S. $800 million in the next five years on R&M projects with loan assistance from the World Bank and the Asian Development Bank. The USAID Mission, New Delhi will be providing grant assistance to PFC to obtain technical guidance and expertise from the U.S. in the overall corporate planning, evaluation of proposals from utilities seeking funds for R&M activities, development of criteria for R&M project selection, and guidelines for funding R&M projects. To some extent, the Central Electricity Authority (CEA) and other GOI agencies in India are providing these services to PFC. However the assistance received so far is fragmented at best and there is a definite need in PFC for a systematic and focused approach to power plant life extension.

In earlier visits to PFC by ORNL and EPRI (March 1990 and July 1990), the possibility of a life extension demonstration project at an Indian utility with a team of Indian and U.S. engineers was discussed. The demonstration project will address all the elements of power plant life assessment and life extension as practiced in U.S. utilities as per the guidelines developed by EPRI. During this meeting, the topic was further discussed.

The current thinking is to involve three groups in the demonstration project. One group will consist of experts from both countries in the boiler side, the second group in the turbine side and the third group will comprise of experts in the balance of plant equipment (coal/ash handling, pulverizers, fans, stack, electrical components, piping and valves etc.). The individual groups will formulate and perform the actual life assessment on the boiler, turbine and balance of plant. The results will be reported to the PFC including the techniques and methods used in the assessment. The individual groups will also be responsible for

coordinating the training of senior officials and plant personnel from the Indian side in the U.S. in each of the three categories. A project advisory group, consisting of experts from the EPRI, the U.S. DOE, the ORNL and consultants from the U.S. and the Indian counterparts will provide technical direction and administrative support during the project implementation. PFC will be making a formal request to USAID through the Minstry of Power to approve the project and to initiate the scope of work.

4. MEETING WITH THE NATIONAL THERMAL POWER CORPORATION (NTPC)

NTPC is a Government of India enterprise and is the largest utility in India with about 10,000 MW of capacity spread over 14 power plants. Almost all the NTPC plants to date are financed by the World Bank and the Asian Development Bank. It is anticipated that West Germany, France and Japan will also provide significant loans for future plants. As an utility operator, NTPC is well-versed in the day-to-day operating problems of their plants and has both in-house staff and consulting engineering companies assisting them in solving their plant problems. The purpose of our meeting was to discuss the role of NTPC in an USAID funded life extension demonstration project with the PFC, CEA and BHEL. The response from NTPC was mixed. NTPC indicated that it would be in their best interest if the demonstration project was carried out at an NTPC site. The reason given was that they have accurate records on plant performance, availability, failure data on components and maintenance records for their own plants. These information which are vital for life assessment are lacking for other state-owned utilities. Even though the NTPC plants are of recent vintage (the oldest is 16 years), they indicated that there are many instances of premature component failures which can be investigated and corrected as part of the demonstration project. The life of the existing plants can also be considerably extended through the demonstration project. Corrective measures for future plants can also be recommended during the design phase itself which will save them a lot of revenue in lost time from component failures. Another reason for choosing an NTPC site is that the NTPC units are 500 MW in size unlike the state-owned units which are 210 MW and smaller in size.

Our assessment is that the NTPC should be involved in any USAID assisted life assessment activity in India.

CONCLUSIONS

Technical assistance was provided to the USAID Mission New Delhi, India in identifying the remaining activities, and the schedule/budget to complete the ongoing coal projects at BHEL, Trichy. The USAID mission and the DNES will decide on the extension of the projects beyond December 1990 with additional funding in October-November 90. Concurrence from USAID Washington will be required before the formal extension is granted for these projects.

In the twelve months since the inception of the Phase II AERD Coal Projects, the projects have progressed successfully from the conceptual stage to an advanced stage of implementation. Major accomplishments to date are (1) the selection, specification and

procurement initiation of equipment for all the four projects have been completed; (2) the engineering design of the FETF has been completed and is to be finalized following the design review at PETC; (3) trial runs on Indian coals in the BHEL slagging combustor have been conducted; (4) the state-of-the-art techniques and methodologies practiced in U.S. utilities for remaining life estimation of power plant components under the EPRI sponsored power plant life extension projects have been communicated to BHEL and Indian utilities. The end results from these USAID collaborative coal projects in India will be a sound technical data base on (1) the combustion characteristic of high-ash Indian coals, (2) performance data on Indian coals in pulverized combustion and other advanced combustion systems, (3) design and operating criteria for achieving higher efficiency and lower pollutant emissions in coal-fired utility boilers in India.

The FETF, when completed, will be the first state-of-the-art combustion research test facility in India. The expertise available at PETC from the operation of a scaled-down version of the FETF is being extensively used in the design of the FETF at Trichy. Continued participation of the PETC and ORNL will be necessary to complete the project.

Benefits to the USDOE and the ORNL from these collaborative coal projects are that they provide a unique opportunity to test and to adapt the coal technologies and products developed by the USDOE for Indian conditions. Potential opportunities will be identified for the U.S. and Indian private sectors for commercial joint ventures in the Indian power sector through the USAID collaborative coal projects.

APPENDIX A

BHEL - USAID Collaborative Projects
USAID Alternative Energy Resources Development Project (386-0474)
Coal Conversion Component Extension

January 1, 1991-June 30, 1992

PROJECT-1. DEVELOPMENT OF POLLUTION CONTROL STRATEGIES FOR ABATEMENT OF NO_x/SO_x EMISSIONS FROM FOSSIL FIRED PLANTS

PROJECT-2. DEVELOPMENT OF SLAGGING COMBUSTOR FOR ADVANCED POWER GENERATION APPLICATIONS

PROJECT-3. ADVANCED DIAGNOSTIC STUDIES FOR PREDICTION OF LIFE EXPECTANCY OF EXISTING POWER PLANTS

PROJECT-4. CHARACTERIZATION OF INDIAN COAL MINERALS FOR COMBUSTION AND GASIFICATION

PROJECT-1

DEVELOPMENT OF POLLUTION CONTROL STRATEGIES FOR ABATEMENT OF NOx/SOx EMISSIONS FROM FOSSIL FIRED PLANTS

1. INTRODUCTION

Currently, there are no emission standards set by any regulatory agency for NO_x and SO_x emissions except for a rule of thumb for the required stack height as a function of plant size.

With the increasing demand for power in the country the trend has been to build several plants in modular sizes of 200 and 500 MW near the coal mines, to avoid transportation costs of high ash coals. This has led to a high concentration of NO_x/SO_x and particulate emissions in the vicinity of these power stations. The ecological damage is a matter of grave concern. It will not be long before all these power plants will be required to install pollution control equipment to reduce the pollutant emissions. In this context, the current design and operational parameters for fossil fired combustion systems will become unacceptable unless adequate measures are initiated now to understand the pollution problem based on actual field measurements and find suitable control methods applicable for "pre-" and "post" combustion.

2. RELEVANCE TO INDIAN NATIONAL POWER GENERATION PROGRAM

The Indian power scenario very much depends on combustion of pulverized coal. At present about 45,000 MW capacity has been installed and every year about 5000 MWs are being added. Further, super thermal power stations with concentrations of multiple 200 and 500 MW units near the coal mines are planned. The cumulative environmental impact of these power plants is fast becoming a matter of national concern. For example, in the thermal power stations at Singrauli, alarming levels of NO_x/SO_x emissions have been noticed by environmental study teams of world bodies.

The significant difference between Indian and U.S. coals with respect to organic and mineral matter content and plant operational conditions makes it difficult to make a one-to-one comparison with U.S. counterpart utilities on the expected NO_x/SO_x emissions from Indian coal-fired plants. Therefore, there is a need for performing experimental studies on Indian coals in utility boilers to quantify the emission levels of NO_x/SO_x and to evaluate the pollution control options.

3. OBJECTIVES

1) Baseline monitoring in selected power plants of India using the state-of-the-art techniques developed in the United States.
2) Evaluate and test burner design and in-furnace control strategies practiced in the U.S. in selected power plants in India.
3) Collect data on NO_x/SO_x and particulates from the Fuel Evaluation Test Facility (FETF) to be erected at Trichy under Project 4.

4. SCOPE OF WORK

The current emission levels of NO_x and SO_x from operating coal fired power plants will be quantified to the extent needed to propose the most efficient and cost effective control strategies for pollution abatement. The proposed project addresses this problem by implementation of the following tasks.

1) Select the most appropriate sampling/analysis techniques for stack NO_x/SO_x measurements in consultation with U.S. experts
2) Acquire the necessary instruments for stack measurements and hands-on experience in operation and calibration of these instruments in U.S.
3) Perform sampling and analysis at selected power plants in India
4) Recommend effective control technologies based on field data.

5. PROJECT SCHEDULE

Tasks	Institutions	Date
1. Identify sampling procedures & instruments for base-line NO_x/SO_x measurement.	PETC, BHEL	10/89-9/90
2. Equipment procurement.	PETC	9/90-12/90
3. Baseline monitoring of NO_x/SO_x in Indian utilities.	ACUREX:BHEL Indian utilities	02/91-04/91
4. Interaction with U.S. experts on NO_x/SO_x monitoring and site-visits to U.S. utilities.	EPRI, ACUREX, PETC, BHEL	6/91-7/91
5. Demonstration of control techniques in an Indian utility.	ACUREX:BHEL	08/91-09/91

6. ACCOMPLISHMENTS AS OF DECEMBER 1990

Tasks 1 and 2 will be completed in December 1990.

7. PROPOSED ACTIVITIES AFTER DECEMBER 1990

Two U.S. experts will participate in the baseline monitoring of NO_x/SO_x with the state-of-the-art equipment in a selected Indian utility. This will be followed by a visit by two BHEL engineers to the U.S. for discussions on the pollutant control options and site-visits to U.S. utilities to participate in the demonstration of control techniques for NO_x/SO_x. A final demonstration of the selected control strategy in an Indian utility will be performed by BHEL.

8. HARDWARE

8.1 USAID Equipment purchased and delivered by December 31, 1990

1. Thermo-Environmental systems
   Model 1400 Extractive Gas Analysis system comprising of

   - Chemiluminescent NO Analyser-Model 10
   - Pulsed Fluorescent SO_2 Analyser-Model 40
   - Gas filter correlation CO Analyser-Model 48
   - Zirconium oxide O_2 Analyser-Model WDG
   - Heated sample conditioner and sample probe-Model 900
   - Data logger-Model 3260
   - Zero Air supply-Model 111
   - Sample Probe-Model 603

2. Acid dew point meter Model 200

3. Fly ash resistivity probe - Portable SRI type point plane resistivity probe

8.2 List of Indigenous Equipment

1) Gas cylinders with regulators stainless steel house (4)
2) Signal cables & connectors
3) Control cubicle with air conditioners
4) Oil pump with motor (1)
5) Filters & strainers (10)
6) Level indicators (8)
7) Flow control valves (5 nos)
8) D.P. switches (5)
9) Flow switch (1)
10) Flow meters (10)
11) Temperature indicator & controller (1)
12) Control panel
13) Temperature indicators (15)
14) Hand regulated valves (10)
15) Power cylinders, solenoid valves manual loaders

16) Digital manometers
17) Recorders
18) Instrument air drier
19) Pressure regulators
20) Air cooled radiator
21) Erection materials
22) Copper tubings & fittings
24) Motor control cabinets
25) Fans with motors

Additional funding required
U.S. $70,100
BHEL Rs. 22.0 lakhs

PROJECT-2

DEVELOPMENT OF SLAGGING COMBUSTOR FOR ADVANCED POWER GENERATION APPLICATIONS

1. INTRODUCTION

Slagging combustors operating in the cyclonic mode burn coal at sufficiently high temperatures to melt the slag and further centrifuge the bulk of the slag on to the walls of the cyclonic combustor. Through suitable orientation of the combustor and the provision of a slag drain zone, the slag centrifuged to the walls drains out of the combustor. This results in the products of the combustion leaving the combustor in "nearly clean" state. Little of the original ash in the coal is carried in the slag form along with the combustion products, and that too, at small sizes (less than 10 microns). The advantages of such clean gases are many like retrofitting oil fired boilers with minimum derating.

This work is closely related to the Indian coal program. If the slag rejection properties of the combustor prove sufficiently promising, direct firing of gas turbines can be visualized for combined cycle systems. Further objectives of the Indian coal programs are the reduction of the capital cost of boiler systems and enhancement of their life. Due to the clean nature of the gases from slagging combustors the plant size will be smaller than conventional pulverized fuel systems. In addition, the solidified slag will be less in quantity and less abrasive than the typical flyash resulting in longer boiler life.

The bulk density of the solidified slag being much higher than that of conventional p.f. boiler ash, its storage, disposal and utilization are easier. Along with the reduction of particulates, this will contribute to environmental protection. Control of NO_x/SO_x without recourse to add-on post-control methods has been demonstrated in the U.S. The commercial implications of the fruits of this project are difficult to predict with any precision at this stage, because of the lack of experience and precise data. However, it is expected that even if the technology is developed for small industrial and utility boilers (up to 60 MW), opportunities exist for the introduction of many slagging combustors in a variety of industrial applications. An added benefit of such systems is its capability to reduce both air pollutant emissions and easy disposal of the solid waste generated in the process.

2. RELEVANCE TO INDIAN COAL PROGRAM

Slagging combustors as an option for future coal fired steam generation appear attractive in the current context of advanced, high-efficiency power generation systems under consideration for future plants in India. Furthermore, the relatively "clean" fuel gas that is generated in the SCC makes it comparable to an oil or gas fired system in terms of the overall power plant size, compactness of the boiler and last but not least less damage to the boilers and downstream components from erosion due to the reduction of the ash loading in the combustion products.

Preliminary information on SCC systems is available at BHEL, Trichy as a result of an ongoing activity in an experimental (3.0 MW) test rig. However, the present understanding of the design, operation, slag property evaluation and pollution control measures through combustor design and operation is inadequate to make a firm recommendation on the viability of this technology for future power plants. If successful, the technology could make a significant impact on the national power program and result in an efficient, compact, environmentally clean system for new and retrofit applications.

3. OBJECTIVES

1) Develop appropriate hardware, screen, select and install suitable non-intrusive diagnostic systems and auxiliary systems for the existing slagging coal combustor (SCC) process development unit at Trichy.

2) Set up a high temperature slag viscosity measurement laboratory for Indian coals differing in ash composition and content and generate a data base on slag properties.

3) Perform parametric tests on selected Indian coals in the SCC facility at Trichy.

4) Develop appropriate flow and combustion models for prediction of combustor performance.

4. SCOPE OF WORK

1) Assistance from experts and institutions in the U.S. on the design of slagging coal combustors and associated hardware, interpretation of data generated in the BHEL pilot scale slagging combustor and selection of instrumentation for the BHEL slagging combustor.

2) Set-up a high temperature slag viscosity measurement laboratory for measuring slag properties of Indian coals for the screening and selection of coals and coal blends for slagging combustors applications.

5. PROJECT SCHEDULE

Tasks	Institutions	Date
1) Commissioning of SCC facility and auxilary systems at Trichy.	BHEL	09/89-5/90
2) Selection of diagnostic equipment.	BHEL, PETC	12/89-6/90
3) Equipment procurement.	PETC	9/90-12/90

4) Design review and modifications to SCC.	BHEL, PETC, Univ. of Tennessee Space Institute (UTSI)	2/91-6/91
5) Testing of coals in SCC and slag property evaluation at Trichy.	BHEL, PETC, UTSI	7/91-10/91
6) Data analysis, interpretation and recommendations for SCC systems.	BHEL, PETC, UTSI	7/91-6/92

6. ACCOMPLISHMENTS AS OF DECEMBER 31, 1990

Tasks 1, 2 and 3 will be completed.

7. PROPOSED ACTIVITIES AFTER DECEMBER 31, 1990

Two BHEL engineers will visit U.S. to participate in discussions and site-visits with U.S. institutions involved in slagging combustor research and development. Suggested modifications to the combustor will be implemented and long duration tests on coals in the Trichy combustor will be initiated following the completion of the visit of BHEL engineers. Two U.S. experts will provide on-site technical assistance during the testing and in the data analysis.

8. HARDWARE

8.1 USAID

1) Two color optical pyrometer with spares and accessories, Model ROS54 Hot Shot Pyrometer
2) Particle size analyzer, Microtrac Model 7998
3) Slag viscometer with spares and accessories, Model Rheotronic VII-E

8.2 BHEL

1) Complete hardware and associated auxillaries for the 3.0 MW(t) SCC test facility including instrumentation.

9. BUDGET

Additional funding required
U.S. $61,312
BHEL Rs. 20.0 lakhs

PROJECT-3

ADVANCED DIAGNOSTIC STUDIES FOR PREDICTION OF LIFE EXPECTANCY OF EXISTING POWER PLANTS

1. INTRODUCTION

Due to increasing costs of setting up new power generation units and the higher cost of maintenance due to frequent failures, there is a critical demand in the utility industry to examine the condition of the components and extend their life by repair or partial replacement. Preliminary studies by BHEL and others have indicated that significant useful life is still left in many older units due to the conservative approaches made in the initial boiler design, and also due to wide scatter in the high temperature properties of the materials. These preliminary studies have been conducted on life estimation in older Indian boilers through dimensional measurements, non-destructive examination (NDE) and in-situ metallography supplemented by bi-axial creep testing in the laboratory.

Among the various approaches currently being evaluated the world over, and particularly in the U.S., the microstructural changes and micro-defects formed during boiler operation are of considerable importance for creep life assessment. Quantitative metallographic techniques are currently being used in the U.S. for evaluating the creep damage. This project envisages acquainting BHEL engineers in these techniques associated with life assessment and remaining life prediction of power plant components. Diagnostic instrumentation, field demonstration of metallographic techniques such as characterization of carbide particles, morphology of carbides, solid solution analysis, creep cavity counting and determination of damage parameters for calculation of remaining life of boiler components will be jointly studied by BHEL and U.S. experts.

2. RELEVANCE TO INDIAN COAL PROGRAM

The current Indian national energy policy is to continue to use even larger amounts of coal. However, the quality of these coals is inferior particularly from the standpoint of ash content. As a result, material degradation in power plant is a common phenomenon which affects plant reliability and expenditure.

Life estimation and life extension are of most interest to power station authorities due to escalating costs of setting up new power stations. A recent study conducted in early 1988 indicates that there are at least fifty power plants, in the size range between 60-120 MW, that are potential candidates for life extension. This is an area which is of high priority in the Indian power sector and the renovation and modernization activities of power plants is expected to form a major part of the proposed capacity addition in the next decade.

3. OBJECTIVES

1) To develop techniques for on-site estimation of life assessment of power plant components.

2) To establish a database on damage mechanisms of power plant components.

3) To provide working knowledge on advanced diagnostic instrumentation and metallographic techniques.

4) To transfer the results to the utility industry for implementation.

4. SCOPE OF WORK

Among the various approaches that are available for life assessment, metallographic methods and steam oxide scale measurement techniques appear to be best suited for the quicker assessment of components working in creep range. Quantitative determinations are being made possible for life prediction and extension through advanced on-site metallographic techniques. The proposed project will draw on the U.S. experience from EPRI, A&E firms, utilities and consultants on current, state-of-the-art instrumentation and methodolgies for remaining useful life (RUL) assessment.

5. SCHEDULE

Tasks	Institutions	Date
1. Collection of power plant reliability and failure data on U.S. and Indian utilities.	BHEL, EPRI North American Reliability Council	10/89-9/90
2. Visit of EPRI staff and EPRI contractors for discussion and seminar with BHEL, NTPC, CPRI and site visits to Indian utilities.	BHEL, EPRI, NTPC, CPRI, PFC, CEA	03/90-08/90
3. Selection and specifications of diagnostic instrumentation for field evaluation of remaining life estimation of power plant components.	BHEL, EPRI, APTEC	06/90-9/90
4. Equipment procurement.	PETC	07/90-12/90
5. Visit of BHEL engineers to U.S. utilities.	BHEL	03/91-4/91

6. Demonstrate life assessment method and technology in Indian utilities.	BHEL, APTECH, EPRI	5/91-7/91
7. Specific recommendation & transfer to Indian utilities.	BHEL, EPRI	07/91-12/91

6. ACCOMPLISHMENTS AS OF DECEMBER 1990

1) The reliability data base on power plant in the U.S. will be completed.
2) Visit of EPRI and other experts to BHEL and Indian power agencies for technical discussions and seminars will be completed.
3) Selection, specifications and procurement of equipment will be completed.

7. PROPOSED ACTIVITIES AFTER DECEMBER 1990

1) Visit of two BHEL engineers to EPRI and U.S. utilities for training and participation in life assessment techniques, prediction of remaining life and maintenance planning of utilities
2) Illustrative case study of methodology and techniques with the advanced diagnostic equipment with two U.S. experts
3) Transfer of technology to Indian utilities through a seminar with two U.S. experts

8. HARDWARE

8.1 USAID SUPPLIES

Equipment	Model	No.
1. Vacuum coating unit and accessories	Bio Rad Microscience	1
2. Sputter coating unit and accessories	Bio Rad, Model SC-500-A	1
3. Portable Mechanical Polishing unit & accessories.	TRANSPOL-2, Struers Inc. OHIO	1
4. Portable Electrolytic Polishing unit & accessories.	MOVIPOL-2, Struers Inc.	1
5. In-situ oxide thickness measurement system.	APTECH Engg. Services AES-P-90-07-1751-6	6

8.2 Indigenous Equipment

1) Datalogger
2) Temperature Controller
3) Three dimensional microscope
4) Spares & Consumables
5) 20 KW electric heater with controls
6) Thermocouples
7) Pressure and temperature gauges and switches
8) Transformers
9) Power 7 controls cables

9. BUDGET

Additional funding required
U.S. $64,508
BHEL Rs. 21 lakhs

PROJECT-4

CHARACTERIZATION OF INDIAN COAL MINERALS FOR COMBUSTION AND GASIFICATION

1. INTRODUCTION

Minerals form an important constituent of coal and as many as 100 of them have been reported in the literature. The majority of the minerals can be classified under one of the four groups viz. aluminosilicates, sulfides, carbonates and silicates.

The Gondwana coal seams in India are minerals characterized by frequent bands of abrasive minerals and carbonate minerals which cause abrasion/erosion and slagging in the combustion system, resulting in forced outages of power plants, and premature failure of equipment.

BHEL has set-up erosion and wear testing laboratories to index the erosion rates of various coals and ashes but the information obtained from these laboratory tests have yet to be interpreted accurately and correlated in terms of the coal type and ash composition.

BHEL's research and development on fixed bed high pressure coal gasification also requires a thorough understanding of coal minerals and their role in the overall gasification process chemistry and problems encountered (clinkering, agglomeration etc.) in the experimental gasification reactors. Erosion is the number one cause of failures in operating power plants in India and the understanding of erosion vis-a-vis coal composition and mineral matter constituents in the coal is crucial in the design of combustion and gasification systems.

2. RELEVANCE TO INDIAN NATIONAL POWER GENERATION PROGRAM

Indian coal formations are of "drift" origin and so the minerals and organics are 'syngenetic'. The mineral content of coals supplied to the power stations are high, often more than 35% with constituents like sandstones, hematite, magnetite, quartzite, siderite, calcite, pyrite, chalcopyrite, carbmaceins, clay etc. This leads to low energy conversion efficiency, shorter plant life and increased environmental impact. The standards like ASTM, BS or DIN have been found to be partially applicable for the Indian coals with high mineral content. New scientific correlations are required for Indian coals to be comparable to similar U.S. conditions.

The problem of mill wear and erosion are high and due to that the operational costs of power plants escalate. The life of pressure parts is also drastically reduced resulting in an increase in related adverse energy efficiency and environmental pollution.

In line with the advanced countries, India is now researching on combined cycle systems with pressurized gasification of coal both in fixed and fluidized beds. The behaviour of the minerals under high pressure is required to compliment this advanced power generation work.

3. OBJECTIVES

1) To design, erect and commission a 3.0 million Btu/h fuel evaluation test facility for conducting controlled experiments on the combustion, heat transfer, pollutant emission and performance characteristics of various Indian coals. The PETC fuel evaluation facility in Pittsburgh will provide the basis for the BHEL test facility.

2) To develop engineering correlations for the optimum design and selection of operating parameters for maximum efficiency and minimum pollutant emissions.

3) To develop an integrated performance code for prediction of performance and emissions from pulverized fuel combustion systems.

4. SCOPE OF WORK

1) Design, erect, and commission a 3.0 million Btu/h capacity tangential fired pollution and emissions control test facility at BHEL, Trichy based on a similar but smaller unit at PETC in Pittsburgh, USA.

2) Testing of two Indian coals at the Pittsburgh Energy Technology Center (PETC) facility and learning methods of coal characterization, pollution related abatement and wear of boiler components due to slagging and fouling.

3) Learning advanced instrumentation and data analysis techniques with the PETC engineers.

4) Generate a data base for Indian coals on slagging, fouling, erosion, combustion and related energy efficiency parameters for heat transfer, and develop correlations for power plant performance prediction by adapting the EPRI Coal Quality Impact Model (CQIM).

5. PROJECT SCHEDULE

Tasks	Institutions	Date
1. Testing of Indian coals at PETC	BHEL/PETC/ORNL	10/90-12/90
2. Specification and procurement of USAID equipment.	PETC/ORNL/BHEL	5/90-12/90
3. Design of FETF facility & review of the design by U.S. experts.	BHEL/PETC/ACUREX and ORNL	5/90-3/91
4. Training of BHEL engineers in U.S. on the coal quality impact model.	PETC/EPRI	5/91-6/91

Tasks	Institutions	Date
5. Erection & commissioning of FETF facility at Trichy.	BHEL/PETC/ORNL	7/91-3/92
6. Shakedown, testing, data gathering and data analysis.	BHEL/PETC/ORNL	3/92-6/92
7. Demonstration of CQIM model at an Indian utility.	BHEL/EPRI/ORNL	4/92-6/92

6. ACCOMPLISHMENTS THROUGH DECEMBER 31, 1990

1) One USAID expert visited India and held detailed discussions and finalized the design features of the proposed 3.0 million Btu/h capacity FETF. The location of the test facility at the R&D site at Trichy, the structural and positional layouts of various equipment and the schemes of the various sub systems have been prepared.

2) List of equipment to be procured through USAID and through indigenous sources have been identified and procurement action on USAID portion completed by PETC (see lists under section 8.0 Hardware)

3) Two solid fuels, one low in ash but slagging in nature (about 8.5 tons) and another high in ash but non-slagging (about 14 tons) have been shipped from Madras, India in the 4th week of August 1990 for testing at PETC.

4) About 30 Indian coal samples have been sent to PETC for their laboratory studies on T_{250} (slag viscosity).

5) BHEL, Trichy has procured a particle feeder, one gm to 10 gm per minute rate, a 2 inch diameter multiple vibratory tubes and commissioned a drop tube testing facility for evaluation of carbon loss with respect to residence time and temperature (1500°C)

6) BHEL has initiated a data base for Indian coals which can list out the organic (combustible matter) and inorganic (mineral matter) properties classified seam wise for each coal field relevant to problems encountered in power plants such as spontaneous ignition, flammability, combustion efficiency, abrasion (mill wear) erosion, slagging, fouling, electrical resistivity of ash and trace element pollution.

7) Stereo microscope equipment has been procured for analysis of the surface angularity (shape) of the various coal associated minerals as found and after breakage.

7. PROPOSED ACTIVITIES AFTER DECEMBER 1990

1) U.S. experts will review the design and manufacturing drawings of the FETF in the U.S. with BHEL and approve the design and manufacturing documents for fabrication at Trichy

2) Two engineers from BHEL will obtain exposure and training on the CQIM in the U.S.

3) On-site assistance of two U.S. experts during the erection and commissioning of the FETF at Trichy

4) A contingency test of two Indian coals in the PETC facility at Pittsburgh Energy Technology Center (PETC) is planned in the event the first tests to be conducted in October-December 1990 are inconclusive.

5) Testing of Indian coals and data analysis will be initiated in the Trichy facility following the shakedown and commissioning with U.S. experts.

8. HARDWARE

8.1 LIST OF EQUIPMENT PROCURED BY USAID BY DECEMBER 31, 1990

	No.
1) Pulverized coal feeders including Microprocessor based control system	4
2) Flame scanner	8
3) Heat traced sample line	100 ft
4) Video system cam recorder	1
- Hitachi monitor	1
- VCR	1
5) Combustion diagnostic instrumentation	2
- Universal Probe Holder	2
- Gas-solid sampling probe	1
- 3 hole pitot tube	1
- 5 hole pitot tube	1
- Total heat flux probe	1
6) Isokinetic sampling system	1
7) Process Management System	1
8) Multistage cyclone & accessories	1
9) Two color optical pyrometer & Accessories	1
10) Haake viscometer with PC based control system and accessories	1
11) Electrical air preheater (220 KW)	1
12) Air cooled radiator	1
13) Level switches	8
14) Digital manometer	1
15) Temperature recorders/Data logger	2
16) Air velocity Meter	1

17) Heat Transfer Fluid	2 drums
18) Smart Version Pressure Transmitters	10
19) Thermocouples	

8.2 List of Indigenous Equipment

1. Castable refractory
2. Castable insulation
3. FD fan
4. Cooling water pump
5. Oil ignitor
6. Air conditioners for control room
7. Flow control valves
8. Thermocouples
9. Panels
10. Trip valves
11. Isolation valves
12. Motor control cabinets
13. Cables
14. Light fittings
15. Erection materials
16. Indicators & Records

9. BUDGET

Additional funding required

U.S. $74,186

BHEL 50 lakhs

APPENDIX B

ITINERARY

R. P. Krishnan

8/30/90-9/1/90	Travel from Oak Ridge to New Delhi, India.
9/3-4/90	Meetings with USAID, BHEL corporate office, NTPC and PFC.
9/5/90	Travel to Bangalore, India.
9/5-6/90	Central Power Research Institute, Bangalore, India.
9/6/90	Travel from Bangalore to Trichy.
9/8/90	BHEL, Trichy, India
9/12/90	Travel from Trichy to New Delhi via Madras
9/13/90	The flight to New Delhi from Madras was delayed by 12 hours and the meetings scheduled for September 13, 1990 had to be postponed to September 14, 1990 and later.
9/14-18/90	New Delhi meetings with USAID, PFC, BHEL, DNES and TERI
9/19/90[1]	Travel from New Delhi to Oak Ridge.

[1]The traveler had to postpone the return from India by two days (originally scheduled to depart New Delhi on September 17, 1990) in order to attend the briefings with GOI officials and BHEL to obtain the necessary customs clearance for the USAID equipment that will be shipped to India in December 1990. The mission requested ORNL and PETC to assist BHEL in this matter.

END

DATE FILMED

11 / 14 / 90